Li/BCX (Thionyl Chloride) Battery for the NASA AN/PRC-112 Survival Radio

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ABSTRACT

As part of the NASA contingency planning related to aborting a launch after liftoff, an emergency radio is required for use by the crew when they return to Earth at some unplanned location. The power source for the radio must be able to satisfy the performance requirements for the radio's mission as well as be compatible with in-cabin storage in the space shuttle. The radio needs a base load power of about 1W with capability to handle power spikes greater than 6.5W. A slightly enlarged battery pack using the Li/BCX chemistry in C-size cells has been developed that meets these power levels and extends the operational life of the radio by over a factor of four compared to its operation using a Li/SO_2 cell battery pack. In addition, the cells meet the requirements for the Li/BCX cells used for extra-vehicular activities by the crew of the shuttle. One of the major qualifying tests is the ability of the cells to withstand exposure to high temperature (149°C) without leaking. Electrical performance and thermal abuse test data will be presented for the cells.

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Objectives

Overall Objective

Develop a battery to power a survival radio to be used by space shuttle crew in case of an emergency termination of a launch after liftoff or inability to land.

Requirements

- compatible with space shuttle requirements for extra-vehicular activities and in-cabin storage

- base load electrical power output of 1W, power spikes to 6.5W

- extend operational life by a factor of four compared to operation using a Li/SO_2 battery

Background

- The AN/PRC-112 is an army radio which was designed with a Li/SO_2 battery consisting of four $^1/_2$ C cells (vent design) in series. This type of battery was deemed unacceptable for use on the space shuttle.

- Li/BCX cells as produced by Wilson Greatbatch Ltd. have a history of successful deployment for space shuttle applications.

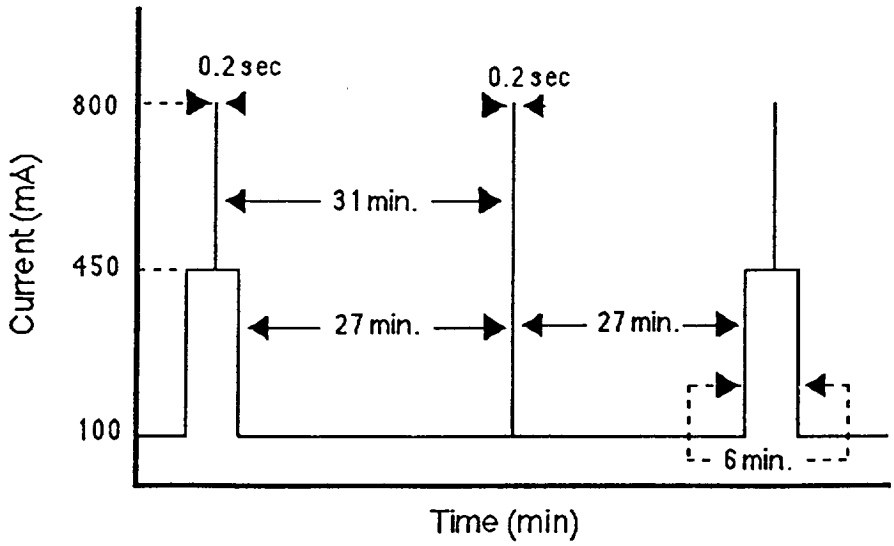
- The previously NASA qualified Li/BCX C cell had insufficient power capability to meet the survival radio electrical requirements. A higher power version was needed.

- A battery consisting of three "universal" Li/BCX C-size cells was proposed.

C-Cell Technical Requirements

- Cell designed to accommodate thermal excursions to 149°C without leaking both prior to use and after discharge.

- Cell must be capable of operating for 43 hours (5.8 Ah) to a 2.7 V cutoff under the radio pulse regimen shown below.



Universal BCX 149 C-Cell Design and Technical Data

outside diameter	1.009 in.
overall length	1.899 in.
nominal weight	58 g
nominal volume	24.9 cm^3
working electrode surface area	110 cm^2
chemistry	Li/BrCl + $SOCl_2$
polarity	case negative
nominal capacity rating	7 Ah
nominal discharge rate	75 mA
maximum continuous rate	1000 mA
nominal specific energy	432 Wh/kg
nominal energy density	0.95 Wh/cc
safety fuse rating	4 A

CELL TESTING

Thermal Abuse Testing

- cells were tested at both 0% DOD and 100% DOD
- cells were heated at a max. rate of 5°F/min. to each of the following temperatures: 200, 225, 250, 275, and 300°F
- each temperature was maintained for at least 15 min.
- after each temperature excursion the cells were cooled to room temp., cell heights were measured, cells were checked for electrolyte leakage.

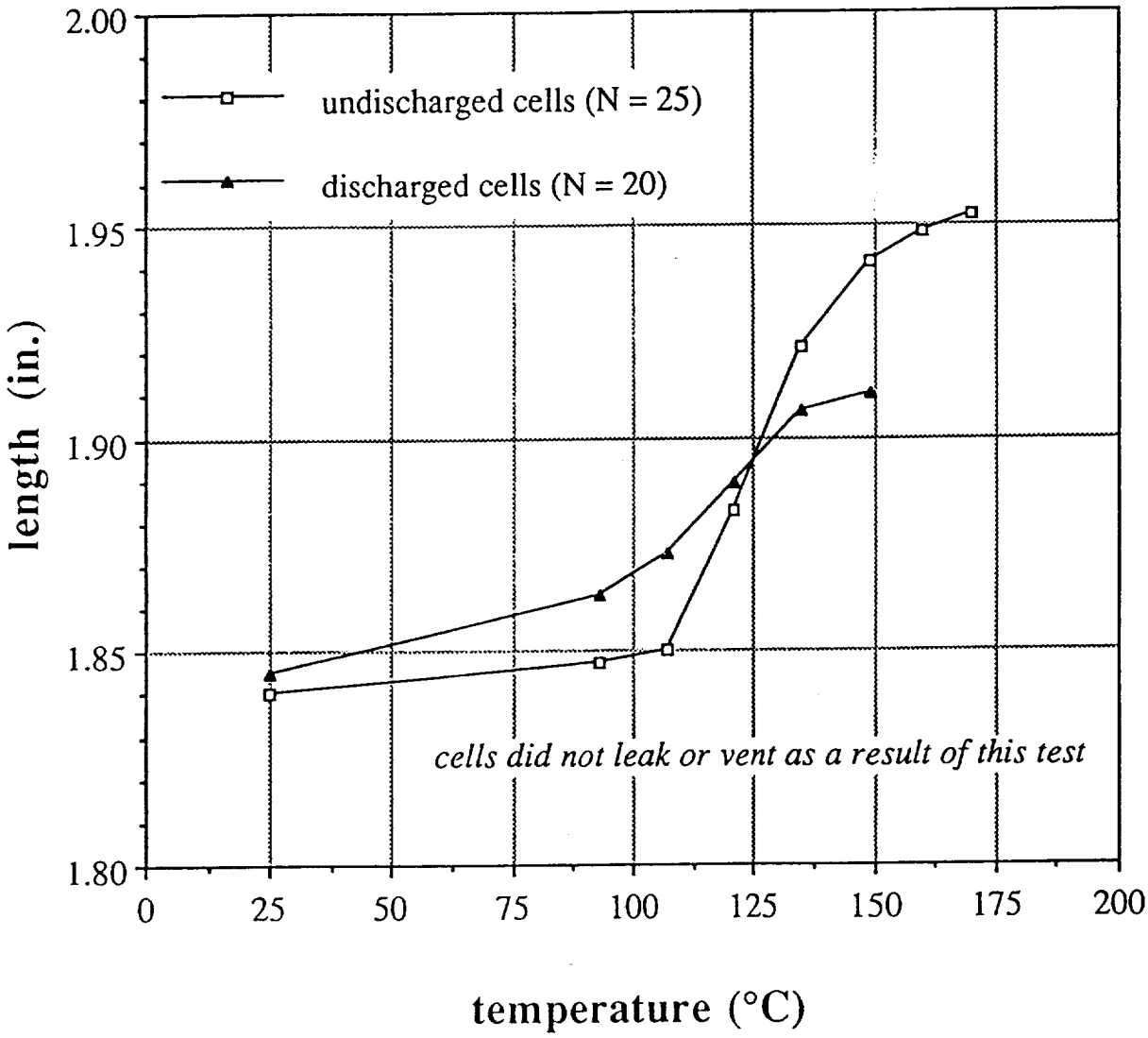
Electrical Abuse Testing

- short-circuit testing through a finite external circuit resistance of 0.5Ω.
- force overdischarge (FOD) testing on discharged cells after 2 weeks end-of-life storage.
  - 3 rates employed: 0.125 A, 0.5 A, and 1 A
  - 2 test temperatures: 21°C and 71°C
  - test duration: 7 hours
  - power source voltage: 38 V

Electrical Discharge Testing

- Testing under constant R loads of 6Ω, 9Ω, 30Ω, and 60Ω conducted at temperatures of -29, 0, 21, 55, and 71°C.
- radio pulse regimen testing at room temp.

Li/BCX (149) C-CELL SWELLING AS A RESULT OF THERMAL CYCLE



Electrical Abuse Testing Results

Short Circuit Testing

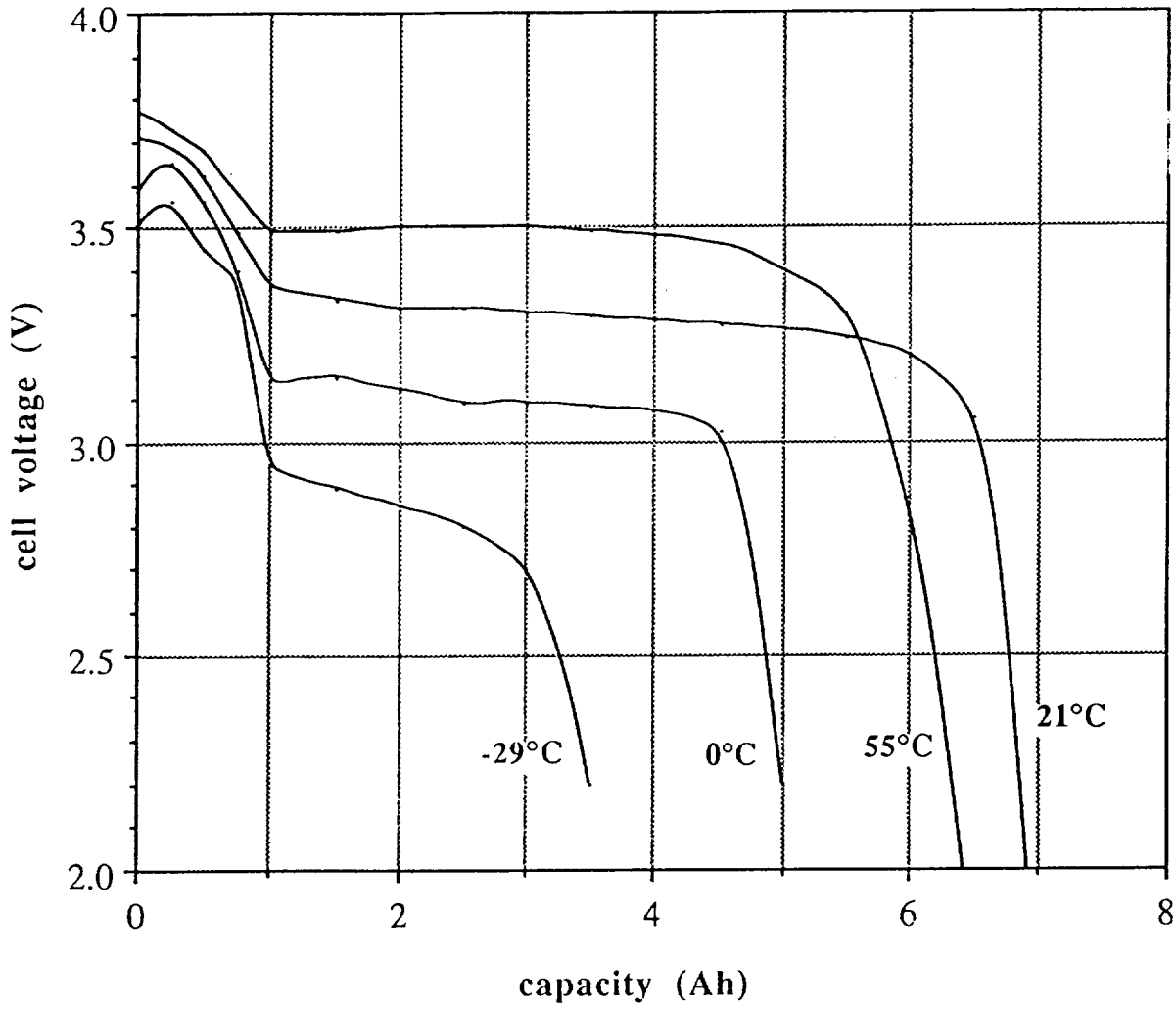
- 52 cells tested
- average initial current: 5.8 A
- average peak temperature: 87°C
- average time to peak temperature: 30 minutes
- no vents, leaks, or ruptures

Force Overdischarge Testing

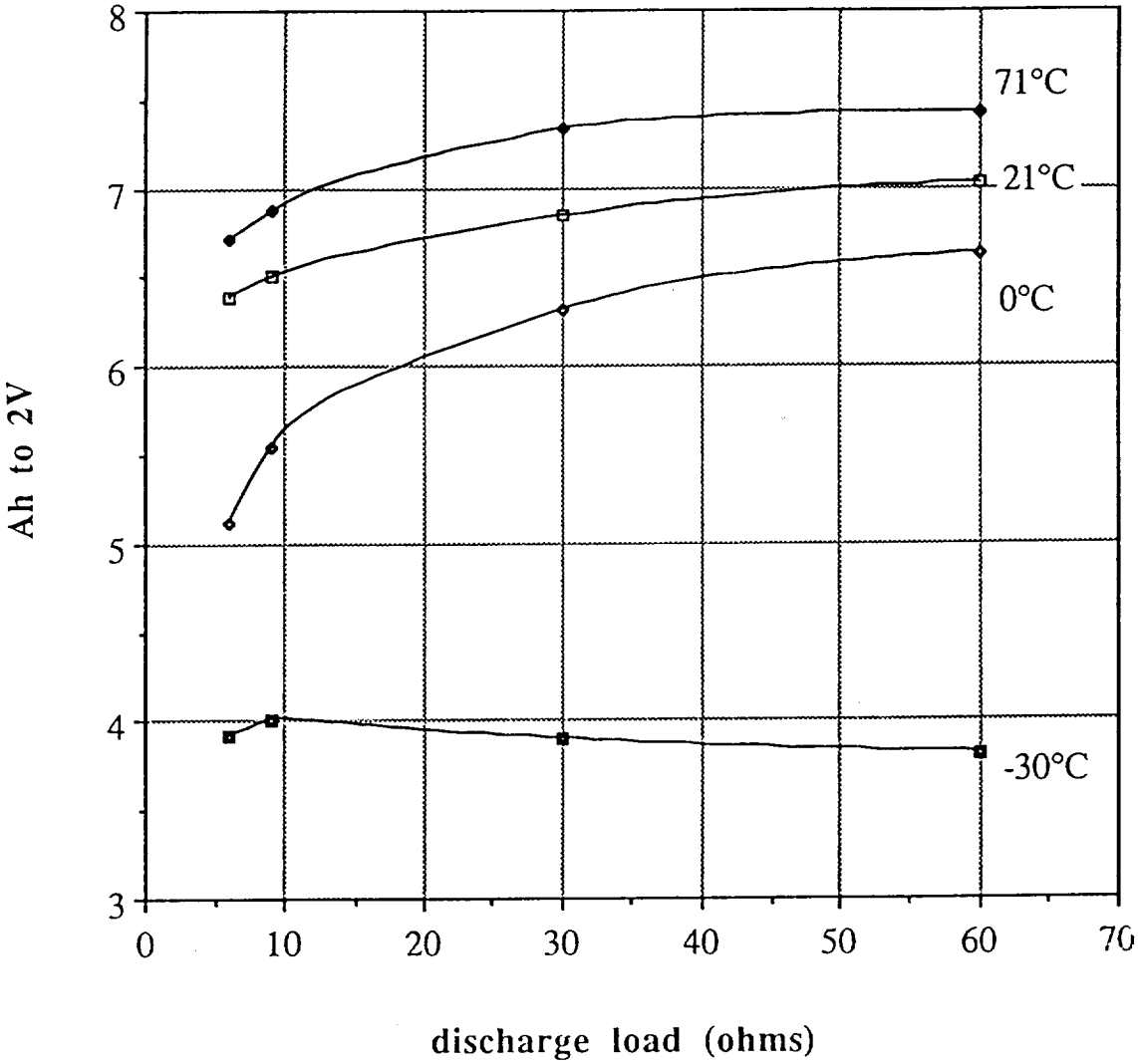
In general...

- current could not be maintained
- cells swelled
- 2 cells mildly vented through glass seal area
- peak temperature exceeded 200°C in some cases
- to-date, 54 cells have been force overdischarge tested

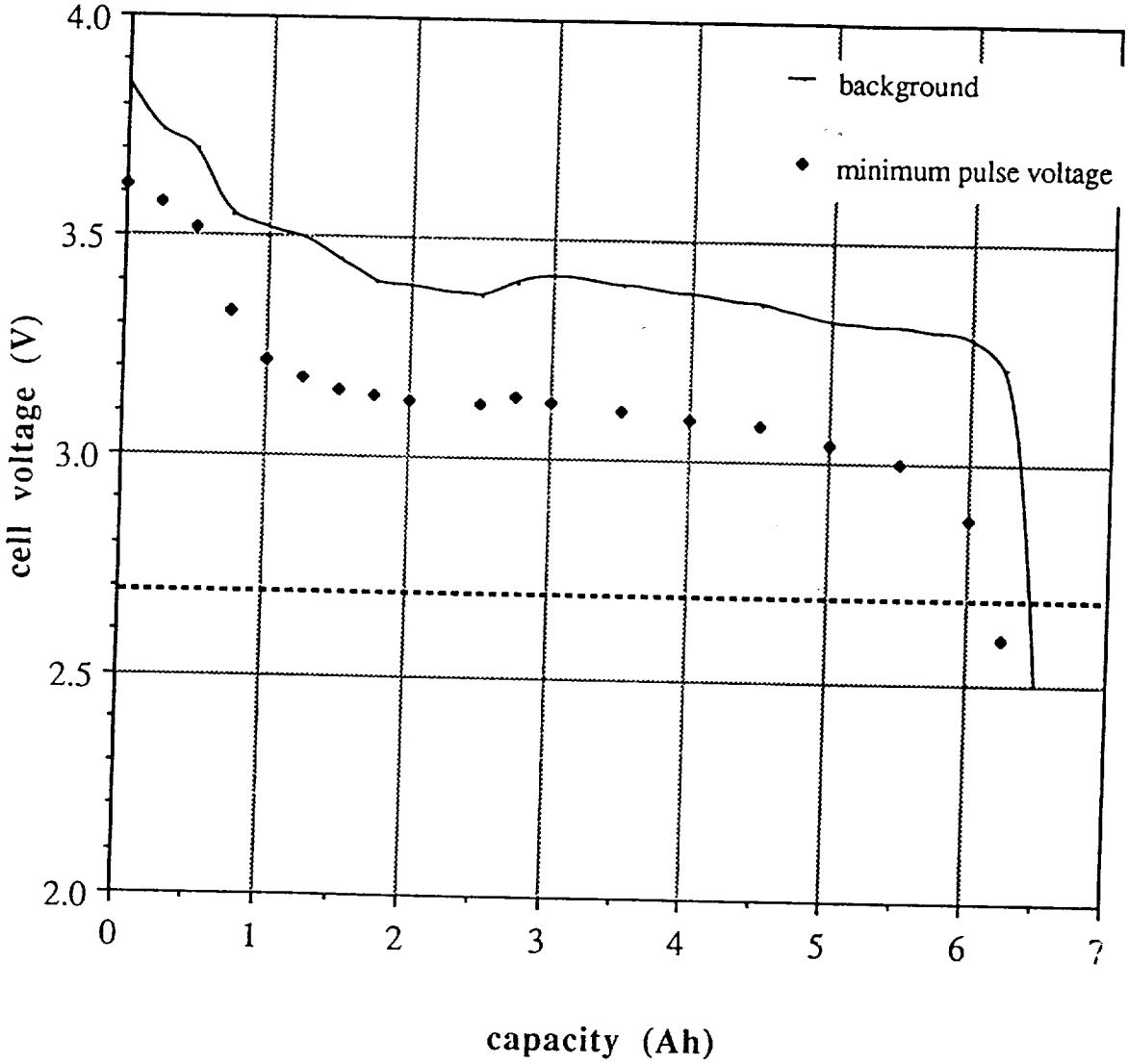
Li/BCX (149) C-CELL DISCHARGE RESULTS UNDER 6Ω LOADS AT VARIOUS TEMPERATURES



BCX 149 C-Cell discharge capacity as a function of load and temperature.



Li/BCX (149) C-CELLS: TYPICAL PERFORMANCE UNDER SURVIVAL RADIO PULSE REGIMEN AT ROOM TEMP.



Battery Technical Requirements

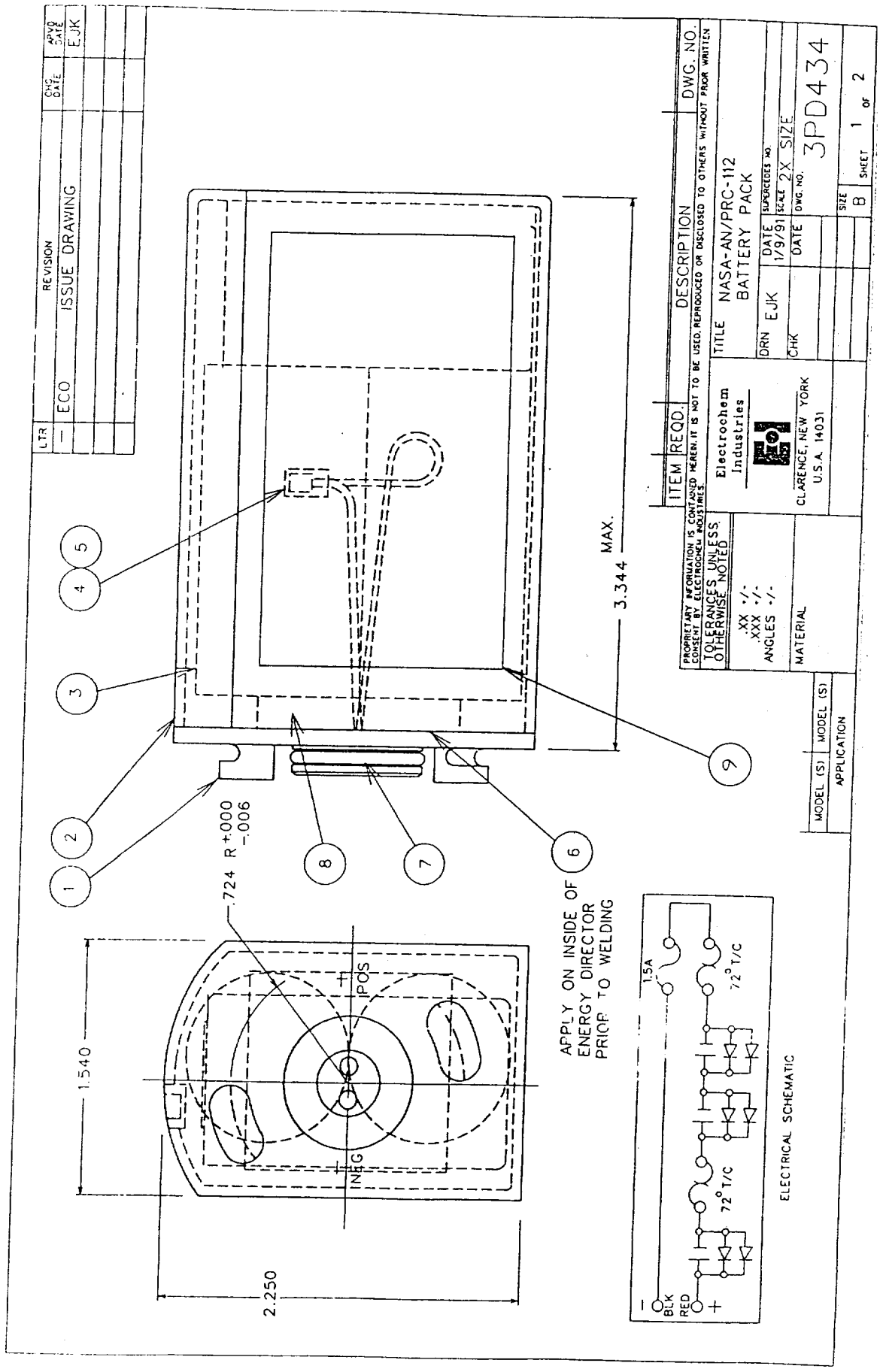
- Designed to accommodate three "universal" Li/BCX C cells in series.

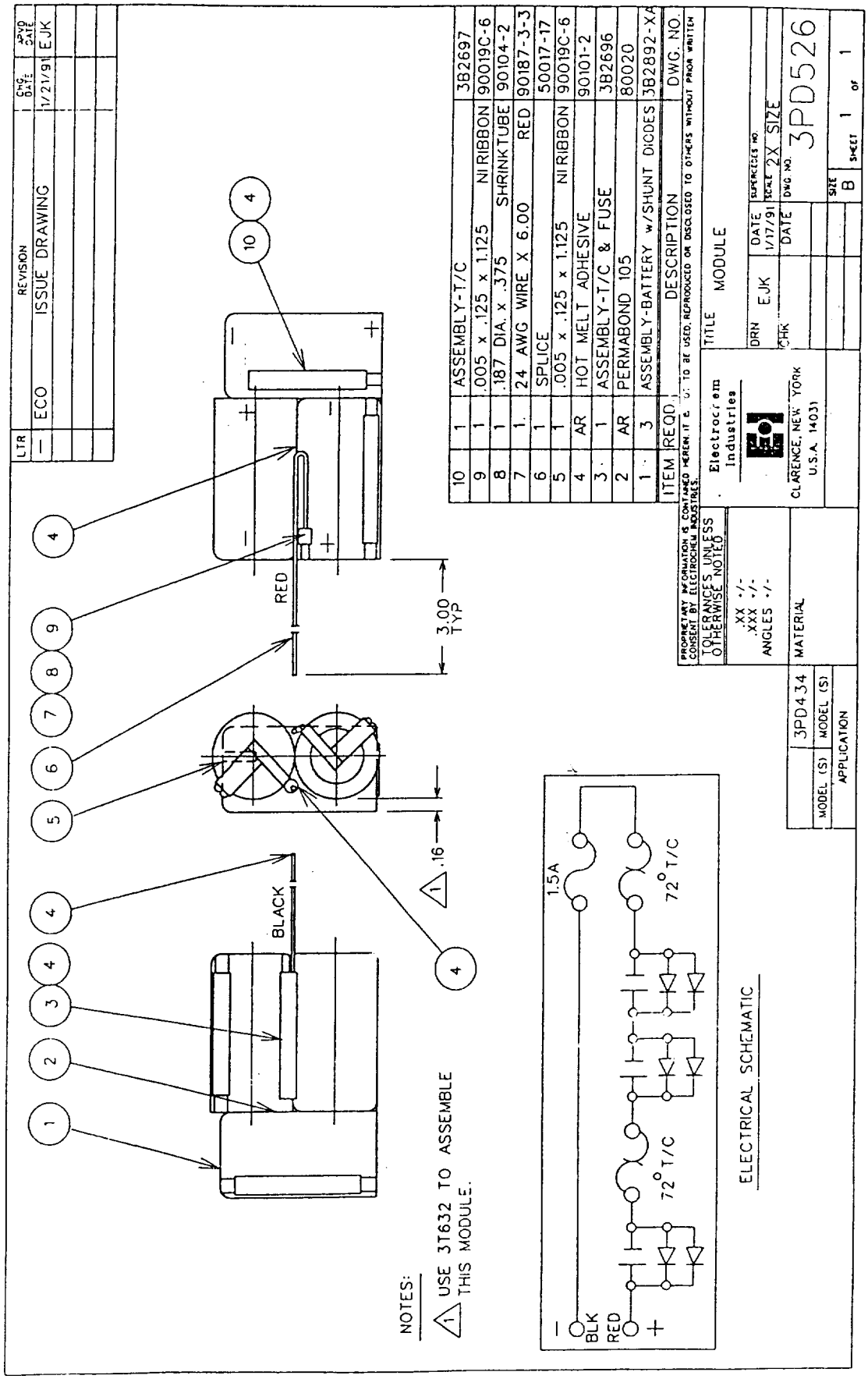
- Safety features to include a 4A fast-blow fuse built into each cell, two shunt diodes in parallel with each cell, two thermal fuses rated at 72°C in the battery, and one 1.5A fast-blow fuse in the negative leg of the battery.

- Battery weight to be 280 g max.

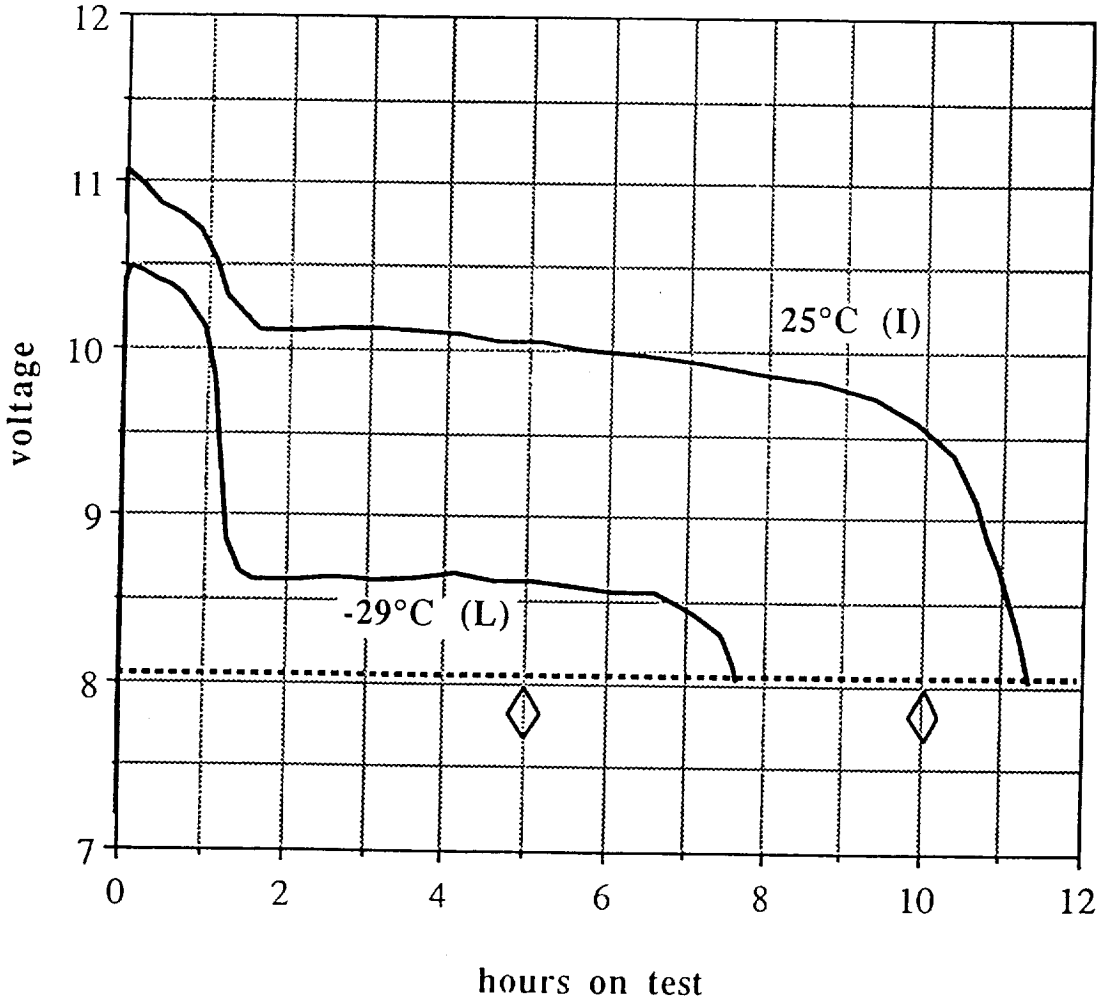
- under 0.5A load at room temperature and higher the battery must attain an 8V minimum operating voltage within 5 sec.

- Capacity rated at 5.0 Ah under a 0.5A load to an 8V cutoff.

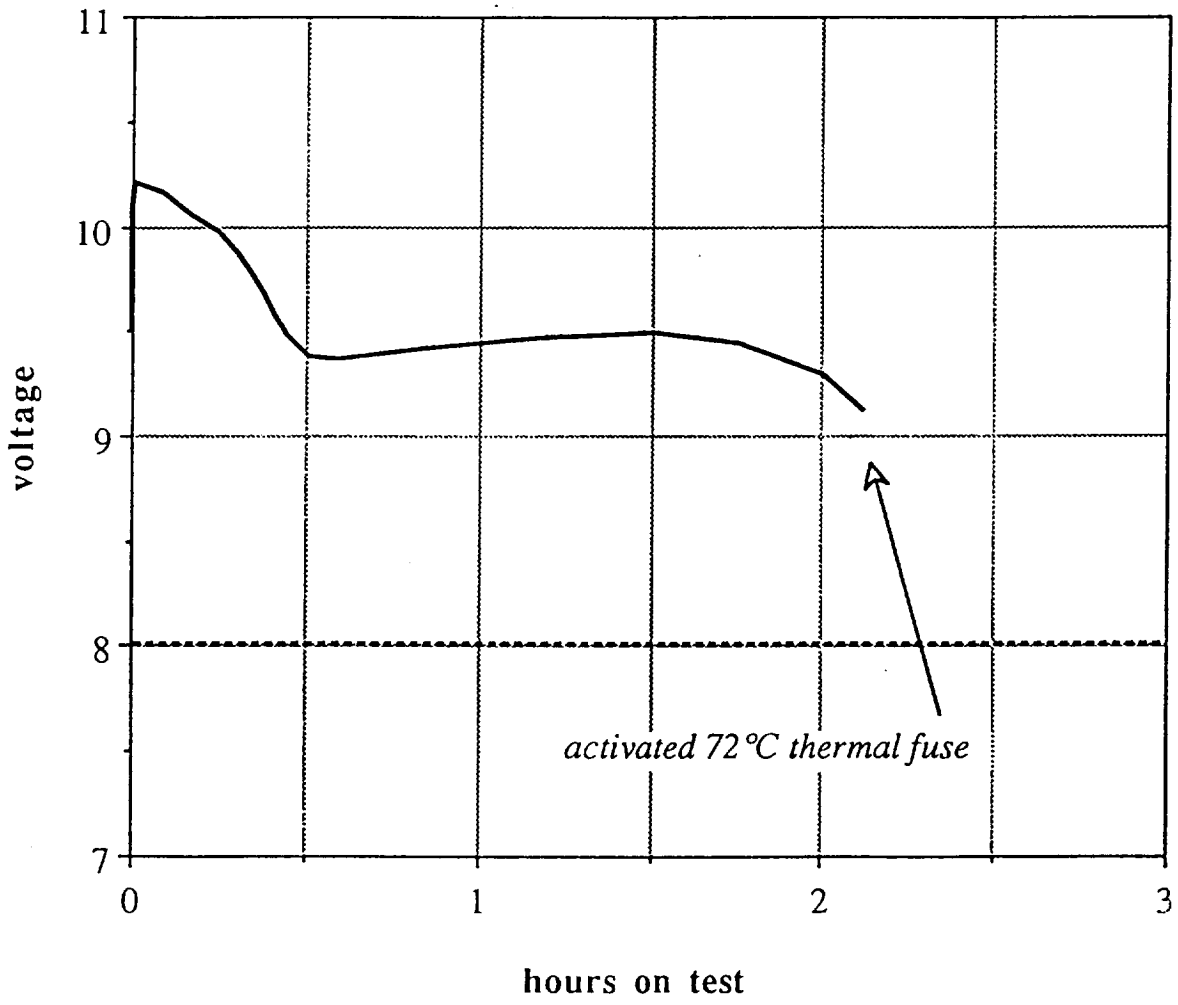

LTR
REVISION
CHG DATE
APVD DATE
—
ECO
ISSUE DRAWING
EJK
DESCRIPTION
ITEM REQD.
DWG. NO.
PROPRIETARY INFORMATION IS CONTAINED HEREIN. IT IS NOT TO BE USED, REPRODUCED OR DISCLOSED TO OTHERS WITHOUT PRIOR WRITTEN CONSENT BY ELECTROCHEM INDUSTRIES.
TOLERANCES UNLESS OTHERWISE NOTED
.XX +/-
.XXX +/-
ANGLES +/-
MATERIAL
Electrochem Industries
CLARENCE, NEW YORK U.S.A. 14031
TITLE
NASA-AN/PRC-112 BATTERY PACK
DRN EJK
DATE 1/9/91
CHK
DATE
SUPERCEDES NO.
SCALE 2X SIZE
DWG. NO.
3PD434
SIZE B
SHEET 1 OF 2
MODEL (S)
MODEL (S)
APPLICATION
3.344 MAX.
.724 R +.000 -.006
1.540
2.250
POS
NEG
APPLY ON INSIDE OF ENERGY DIRECTOR PRIOR TO WELDING
1.5A
72° T/C
72° T/C
BLK
RED
ELECTRICAL SCHEMATIC


REVISION
LTR
ECO
ISSUE DRAWING
ENG DATE
1/21/91
APVD DATE
EJK
ITEM
QTY REQD
DESCRIPTION
DWG. NO.
10 1 ASSEMBLY-T/C 3B2697
9 1 .005 x .125 x 1.125 NI RIBBON 90019C-6
8 1 .187 DIA. x .375 SHRINKTUBE 90104-2
7 1 24 AWG WIRE X 6.00 RED 90187-3-3
6 1 SPLICE 50017-17
5 1 .005 x .125 x 1.125 NI RIBBON 90019C-6
4 AR HOT MELT ADHESIVE 90101-2
3 1 ASSEMBLY-T/C & FUSE 3B2696
2 AR PERMABOND 105 80020
1 3 ASSEMBLY-BATTERY w/SHUNT DIODES 3B2892-XA
PROPRIETARY INFORMATION IS CONTAINED HEREIN. IT IS NOT TO BE USED, REPRODUCED OR DISCLOSED TO OTHERS WITHOUT PRIOR WRITTEN CONSENT BY ELECTROCHEM INDUSTRIES.
TOLERANCES UNLESS OTHERWISE NOTED
.XX +/-
.XXX +/-
ANGLES +/-
Electrochem Industries
CLARENCE, NEW YORK U.S.A. 14031
TITLE MODULE
DRN EJK
CHK
DATE 1/17/91
DATE
SUPERCEDES NO.
SCALE 2X SIZE
DWG NO. 3PD526
SIZE B
SHEET 1 OF 1
3PD434
MODEL (S)
MODEL (S)
APPLICATION
MATERIAL
RED
BLACK
3.00 TYP
.16
NOTES:
1 USE 3T632 TO ASSEMBLE THIS MODULE.
ELECTRICAL SCHEMATIC
1.5A
72° T/C
72° T/C
BLK
RED

NASA AN/PRC-112 Battery
L and I test: 0.5A discharge



NASA AN/PRC-112 Battery
HR test: 1.5 A discharge at room temp.



Battery Environmental Testing

Shock Testing

- sawtooth pulse of 20 ± 0.5 g peak for an 11 msec rise and 1 msec decay in both directions of 3 perpendicular axes
  - batteries passed (no leak, vent, or rupture)

Vibration Testing

- 12.1 ± 0.1 min. in each of three mutually perpendicular axes according to the following spectrum:

20 - 150 Hz	+ 6 dB/octave
150 - 1000 Hz	0.03 g^2/Hz
1000 - 2000 Hz	- 6 dB/octave

  - batteries passed (no leak, vent, or rupture)

Altitude

- rapid decompression to 100,000 ft within 3 sec.
  - batteries passed

Leakage

- helium leak rate less than 1.4×10^{-5} cc/sec
  - batteries passed, average leak rate was 5.8×10^{-7} cc/sec

SUMMARY

- An updated BCX 149 C-cell/battery has been designed for the AN/PRC-112 survival radio battery and is nearing qualification for extra-vehicular activities and in-cabin shuttle deployment.

- The battery has demonstrated power outputs of 1 W with power spikes to 6.5 W.

- The BCX battery will extend the operating life by a factor of four compared to operation using a Li/SO_2 battery.

- Qualification testing will be complete during the second half of Nov91.